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CRASH CUSHION WITH DEFLECTOR SKIN

BACKGROUND

The present invention relates to a crash cushion, and in particular to a crash cushion having one or more deflector skins adapted to redirect a laterally impacting vehicle, and methods for the use thereof.

Roadways are often configured or lined with protective crash barriers that protect drivers from various rigid objects, such as bridge abutments, guardrails and other obstructions. Likewise, slow moving vehicles, such as trucks, can be outfitted with truck-mounted attenuators to attenuate the impact of vehicle striking them from the rear. In various configurations, highway crash barriers and truck-mounted attenuators can be constructed of an array of compressible, resilient, energy-absorbing cylinders positioned in front of or alongside the rigid object. In operation, and in particular during an axial impact, the cylinders are compressed and absorb the energy of the impacting vehicle, thereby decelerating the vehicle in a controlled manner. However, during a lateral impact, the vehicle may tend to snag or pocket one or more of the cylinders at gaps formed between the outer curved surfaces of adjacent cylinders.

To combat this problem, crash barriers have been provided with one or more cables strung alongside the crash barrier between the barrier and the roadway, as shown for example in U.S. Patent Nos. 5,011,326 and 5,403,112 to Carney III. The cables span the gaps between adjacent cylinders and assist in redirecting the errant vehicle back onto the roadway.

Another solution to avoid pocketing of the vehicle in the array of cylinders is shown in U.S. Patent No. 3,845,936 to Boedecker. In particular, a series of sheet-like fish scales are positioned between the cylinders and the roadway. The fish scales are attached to selected ones of the cylinders. The fish scales are relatively expensive structurally rigid plates that are attached to the cylinders in a relatively complex manner.

SUMMARY

By way of introduction, various preferred embodiments of the crash cushion described below include a cylinder, preferably resilient and self-restoring, having a substantially vertical longitudinal axis and an outer surface comprising a curved portion adapted to be exposed to a roadway. A deflector skin has a curved contour shaped to mate with the curved portion of the outer surface of the cylinder. The deflector skin is mounted to the cylinder on the outer surface over at least a portion of the curved portion of the outer surface.

In one aspect, one preferred embodiment of crash cushion system includes an array of cylinders having a side and at least one deflector skin which is mounted to at least one of the cylinders on the outer surface thereof over at least a portion of the curved portion that defines part of the side of the array. In a preferred embodiment a plurality of deflector skins are each mounted to a corresponding one of the cylinders.

In another aspect, one preferred embodiment of the crash cushion system includes a plurality of cylinders, at least some of which define a side of the array. Each of the cylinders defining the side of the array has an outermost vertical tangent, and the combination of such tangents preferably defines a vertical plane. At least one, and preferably a plurality of deflector skins, each including a leading edge and a trailing edge, is mounted to a corresponding one of the cylinders forwardly of the tangent. In one preferred embodiment, the deflector skins are substantially flat and are oriented in a non-parallel relationship with the vertical plane. Preferably, only the leading edge of the deflector skins is mounted to the cylinder, with the trailing edge being a free edge.

In one preferred embodiment, the crash cushion assembly includes a plurality of first and second deflector skins mounted to corresponding cylinders. Preferably, the second, outer deflector skin has a greater thickness than the first, inner deflector skin.

In another aspect, one preferred embodiment of a method for attenuating the impact of a vehicle striking a crash cushion system includes impacting a side of a crash cushion and thereby impacting at least one of the deflector skins. In

another preferred embodiment, the method includes impacting a front of the crash cushion and thereby compressing at least some of the cylinders, but without substantially deforming one or more of the deflector skins. In one preferred embodiment, the frontal impact includes deforming at least one of the first curved deflector skins without substantially deforming the second deflector skins secured along only the leading edges thereof.

In another aspect, a method of assembling a crash cushion system includes arranging a plurality of cylinders in an array, positioning cylinders having a deflector skin along a side of the array and orienting the cylinders with deflector skins with the skins facing outwardly from the side of the array.

The various preferred embodiments provide significant advantages over other crash cushions. In particular, the cylinders can each be individually configured with one or more deflector skins. Accordingly, the cylinders can be easily arranged or configured in different arrays without expensive customization. Moreover, if one or more cylinders or deflector skins are damaged, they can be easily replaced.

In addition, in one preferred embodiment, the deflector skin having a leading edge mounted in front of the tangent and a free edge extending away therefrom can be angled out of the plane of the side of the array so as to provide resistance to penetration, scoring and/or gouging of the cylinders during the initial impact of a vehicle at an angle to the side of the crash cushion. Moreover, since the deflector skin is preferably secured along only one edge, it is not substantially deformed during a frontal, or axial, impact and does not interfere with the operation of the energy absorbing cylinders.

The inner, curved deflector skins also provide the advantage of providing a lower coefficient of friction than the underlying cylinder, such that the vehicle tends to slide along the deflector skin. Moreover, the deflector skin acts as armor plating, and is not as easily gouged as the underlying cylinder, so as to further avoid snagging of the impacting vehicle. Preferably, the inner deflector skin is thinner than the outer deflector skin, and thereby can bend and deform with the cylinder during a frontal impact. Moreover, the positioning of the deflector skins

provides discrete protection for the cylinders in the area vulnerable to a lateral impact, yet does not interfere with the overall operation of the system.

The foregoing paragraphs have been provided by way of general introduction, and are not intended to limit the scope of the following claims. The presently preferred embodiments, together with further advantages, will be best understood by reference to the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a perspective view of a crash cushion system.

FIGURE 2 is an enlarged partial perspective view of the crash cushion system shown in Figure 1.

FIGURE 3 is a top view of the crash cushion system shown in Figure 1.

FIGURE 4 is a side view of the crash cushion system shown in Figure 1.

FIGURE 5 is a perspective view of a cylinder with a first and second deflector skin mounted thereto.

FIGURE 6 is a front view of the cylinder shown in Figure 5.

FIGURE 7 is a rear view of the cylinder shown in Figure 5 with the cylinder rotated approximately, 180 degrees relative to the view of Figure 6.

FIGURE 8 is a top view of the cylinder shown in Figure 5.

FIGURE 9 is a top view of a plurality of cylinders in a compressed or deformed state.

FIGURE 10 is a top view of an alternative embodiment of a crash cushion system.

FIGURE 11 is a top view of an alternative embodiment of a crash cushion system.

FIGURE 12 is a perspective view of a transverse frame structure slidably engaging a rail and forming part of the crash cushion system shown in Figure 1.

FIGURE 13 is a perspective view of an alternative embodiment of a crash cushion system.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EMBODIMENTS

Referring to FIGS. 1-4, one preferred embodiment of a crash cushion **2**, otherwise referred to as a vehicle impact attenuator, is shown in an initial position, prior to impact. The crash cushion **2** has a front **4** facing the flow of oncoming traffic and a rear **6** positioned adjacent to a backup **10**, which can be any hazard alongside a roadway. Typically, the backup **10** is a rigid object, such as a bridge abutment, tollbooth, wall, guardrail, moving vehicle such as a truck, or other obstruction positioned in or along the roadway. The crash cushion **2** also has a pair of opposite sides **8**, at least one of which is exposed to the roadway and the flow of traffic. In one embodiment, shown in FIGS. 1-4, both of the sides **8** are exposed to the traffic flow, for example when the crash cushion **2** is positioned in front of a tollbooth. In other embodiments, the crash cushion **2** may have only one side exposed to the traffic, with the other side facing away from the traveled lanes of the roadway, and which may be positioned along a backup, or other rigid object. Of course, both the rear and one side, or one side only, may be positioned adjacent a backup to provide protection thereagainst.

In another embodiment (not shown), the crash cushion is mounted to the rear of a vehicle, such as a truck. In such an embodiment, it should be understood that the front of the crash cushion is the portion facing the flow of traffic farthest from the rear of the vehicle to which it is mounted, with the rear of the crash cushion being closest to the rear of the vehicle.

In yet another embodiment, shown in FIG. 13, the crash cushion **2** is positioned behind a first rigid object **80**, shown as a tapered transition barrier, and along side a second rigid object **82**, shown as a wall, such that the front of the crash cushion is positioned closest the first rigid object **80**. The first and second rigid objects **80, 82** can be made separate or integral, for example by concrete casting. The crash cushion includes an array **90** of cylinders **14** that are secured to each other and to the wall **82**. This crash cushion configuration, without deflector skins, is available from Energy Absorption Systems, Inc., having offices in

Chicago, Illinois and which is the assignee of the present application, as the CushionWall II™ system.

Referring to FIGS. 1-4, the crash cushion **2** preferably includes an array **12** of tubes, preferably formed as cylinders **14**. It should be understood that the term "cylinder" as used herein means any upright member, and is not limited to a member having a circular cross-section, but may be configured with an elliptical cross-section, or other symmetrical or non-symmetrical cross-sections, including for example rectangular and triangular cross-sections. Preferably, but without limitation, at least a portion of the outer surface of the cylinder (which outer surface preferably may be linear or curvilinear or some combination thereof) is defined by a continuum of points maintained in the same orientation, but not necessarily at a fixed distance, relative to a vertically oriented axis as the continuum is moved about the axis. For example, in one preferred embodiment, the continuum of points is formed as a vertical line, which is moved parallel to the axis to form the cylinder.

Referring to FIGS. 5-8, each cylinder **14** is preferably oriented with a longitudinal axis **16** positioned substantially vertically. It should be understood that the term "longitudinal," as used herein, means of or relating to length or the lengthwise direction, for example from the front **4** to the rear **6** of the crash cushion **2**, or from the bottom to the top of the cylinder. The term "laterally," as used herein means situated on, directed toward or running from side to side of the crash cushion, or directed at the side of the crash cushion along a trajectory non-parallel thereto.

The cylinders **14** each have an outer circumferential surface **18** and are formed by a wall **22** having thickness. Preferably, the wall thickness is less than about 3 inches, more preferably between about 0.5 and 2.0 inches, and most preferably between about 0.75 inches and about 1.75 inches. In one preferred embodiment, the cylinders **14** each have an outer diameter of about 24 inches and a length or height of about 40 inches. Of course, it should be understood that other shapes and sizes would also work as explained above. For example, the cylinders can be configured with alternative cross-sections, such as ellipses, ovals

and the like, each of which has an outer curved surface presented to the traffic flow, with the outer curved surface having an outermost tangent. In one alternative embodiment, an upright member, for example a wall, is configured with a plurality of outer convex surfaces that face outwardly toward the flow of traffic.

The cylinders are preferably made of a resilient, polymeric material, such as high-density polyethylene (HDPE), including for example high molecular weight (HMW HDPE) high-density polyethyelene, such that the cylinders are self-restoring after impact. One suitable material is HDPE 3408. In other preferred embodiment, the cylinders are made of elastomeric materials, such as rubber, or combinations of polymeric and elastomeric materials. As used herein, the term "self-restoring" means that the cylinders return substantially (though not in all cases completely) to their original condition after at least some impacts. Therefore, to be self-restoring, the cylinder does not have to return to exactly its original condition. The term "resilient," as used herein, means capable of withstanding shock without permanent deformation or rupture. Of course, it should be understood that the cylinders can be made of other materials, and can be solid rather than hollow, or can be filled with various materials, such as water or sand. The cylinders **14** each deform resiliently in response to compressive loads extending along a diameter of the cylinder, thereby providing forces that tend to slow an impacting vehicle. The resiliency of the individual cylinders restores the cylinders substantially to the original configuration after the impact, and preferably after many impacts.

In one preferred embodiment, shown in FIGS. 1-4, the array **12** defines a longitudinal direction **20** extending forwardly from the backup **10**. In one preferred embodiment, the front **4** is positioned farther from the backup **10** than the rear **6**. Again, in other preferred embodiments, the front **4** and/or one side **8** of the array can be secured to or positioned adjacent a backup. The cylinders **14** are preferably secured together and to the backup **10**, whether directly or by way of intervening frame members **28**. The array preferably includes a plurality of cylinders **14**, preferably including a plurality of rows of the cylinders, with each

row having at least one cylinder. The term "plurality" as used herein means more than one, or two or more. In this example, each of the rows includes two cylinders **14**, each disposed on a respective side of the centerline of the array, which centerline is aligned in the longitudinal direction **20**. Preferably, each of these cylinders **14** includes a compression element **24** that is designed to resist compression of the respective cylinder **14** along a respective compression axis, while allowing elongation of the cylinder **14** along the same axis and collapse of the cylinder parallel to the longitudinal direction **20** of the array. The term "compression element," as used herein, is intended to encompass a wide variety of structures that effectively resist compressive loads along a compression axis while allowing substantial compression in at least some other direction. One preferred embodiment of a compression element is described and shown in U.S. Patent Application S/N 09/799,905, filed March 5, 2001, entitled "Energy-Absorbing Assembly For Roadside Impact Attenuator," and assigned to the assignee of the present invention, the entire disclosure of which is hereby incorporated herein by reference.

In the preferred embodiment shown in FIGS. 1-4 and 12, an elongated structure takes the form of a rail **26** that is secured in place in alignment with the longitudinal direction **20**, for example, by bolting the rail to a support surface. This rail **26** may take the form of the rail described in U.S. Patent 5,733,062, assigned to the assignee of the present invention and hereby incorporated by reference. The crash cushion also includes a plurality of frame members **28**. In this embodiment, each of the frame members **28** includes one or more transverse elements **30** that are secured to adjacent ones of the cylinders **14** in each row and is configured with guides **29**, shown in FIG. 12, which slide along the length of the rail **26** in an axial impact. The guides **29** are captured under a top portion of the rail **26** and restrain lateral movement of the frame member **28** while simultaneously permitting axial movement in the longitudinal direction **20**.

In an axial impact, the frame members **28** slide along the rail **26**, and the cylinders **14** are flattened along the longitudinal direction. Deformation of the cylinders **14** absorbs kinetic energy and decelerates the impacting vehicle.

In a lateral impact, the compression elements **24** transfer compressive loads to the transverse elements **30**, which in turn transfer the compressive loads to the rail **26** by way of the guides **29**. This provides substantial lateral stiffness to the crash cushion such that the crash cushion redirects an impacting vehicle that strikes the crash cushion laterally. Because the frame members **28**, guides **29** and the elongated structure, including the rail **26**, are positioned inboard of the vertically oriented outermost tangents of the cylinders **14**, a vehicle traveling down the side **8** of the crash cushion **2** cannot engage the guides or the elongated structure in a fashion likely to cause snagging of the impacting vehicle.

It should be understood that pluralities of the cylinders **14** can be configured in many different arrays, and that the crash cushion embodiment shown in FIGS. 1-4, with its rail, frame members including the transverse elements and compression elements, is meant to be exemplary rather than limiting. For example, as shown in FIGS. 10 and 11, a plurality of cylinders **14** can be arranged in various arrays **32, 34**, with the cylinders being mounted directly to one another, or to a frame structure. The array can be symmetrical; or asymmetrical, and the cylinders can be configured with or without compression elements. The array **34, 90** can include, for example and without limitation, a single column of cylinders **14**, as shown in FIG. 10 and 13, or can be configured with multiple columns of equal numbers of cylinders, or in a triangular configuration, as shown in FIG. 11, or in any other arrangement having at least one impact side **8** that is exposed to traffic.

Referring to FIGS. 3, 10 and 11, the array **12, 32, 34** has a side **8** defined by the outermost half, or outer semi-circular portion **36**, of the circumferential surface **18** of the outermost cylinders in the array. When the outermost cylinders are arranged linearly, in a column, as shown in each of FIGS. 3, 10 and 11, approximately 180° of the outer circumferential surface **18** relative to the center of each cylinder forms and defines the side **8** of the array. It should be understood, however, that if the cylinders positioned along and defining the side of the array are not arranged linearly, a greater or lesser amount of the circumferential surface of each cylinder will form and define the side. In the preferred embodiment,

where an outermost column of cylinders **14** is arranged linearly to define the side **8** of the array, each cylinder **14** has a vertically oriented outermost tangent **38**, with the combination of the tangents **38** defining a substantially vertical plane **40**.

Referring to FIGS. 1-4, in one preferred embodiment, each of a selected number of the plurality of cylinders **14** defining the side **8** of the array is configured with a first and second deflector skin **42, 44**. Likewise, as shown in FIGS. 10 and 11, the cylinders **14** defining at least one side **8** of the array are each configured with a first and second deflector skin **42, 44**. It should be understood that the system could include only a single cylinder configured with one or both of the first and second deflector skins, but that preferably a plurality of cylinders forming the side of the array are so configured. Of course, it should be understood that not all of the cylinders forming the side need be so configured.

Referring to one preferred embodiment of the cylinder shown in FIGS. 5-8, the first deflector skin **42** has a curved contour that is shaped to mate with the outer surface of a corresponding one of the cylinders **14** to which it is secured. In this way, the deflector skin **42** is preferably formed as an arc shaped panel, or plate. Preferably, the deflector skin **42** is made of a thin sheet of metal, such as an 18 gauge CR (cold-rolled) sheet, which has a lower coefficient of friction relative to the vehicle or wheel than does the cylinder **14**. Of course, it should be understood that the deflector skin can be made of other metals, including other steels, aluminum or titanium, or various plastics or polymeric materials and/or combinations thereof. Moreover, the deflector skin can be made as a laminate structure, with various substrates being made of different materials. In one preferred embodiment, the deflector skin **42** has a width of about 23-7/8 inches and a height of about 24 inches.

Preferably, the first deflector skin **42** is centered on the cylinder **14** about the tangent **38** of the cylinder to which it is secured or mounted, with the first deflector skin extending equal amounts forwardly and rearwardly from the tangent. In other embodiments, the first deflector skin is not centered about the tangent, and may even be positioned entirely in front of or behind the tangent. In one preferred embodiment, the first deflector skin **42** has a leading edge **46** and a

trailing edge **48**, both of which are preferably secured to the cylinder **14**. The deflector skin **42** has an inner surface **50** and an outer surface **52**. In one preferred embodiment, the inner surface **50** is abutted against the outer surface **18** of the cylinder, and a washer bar **54** is positioned on the outer surface **52** of the deflector skin adjacent the trailing edge **48**. In one preferred embodiment, where the deflector skin **44** is omitted, a second washer bar **54** is positioned on the outer surface **52** of the deflector skin **42** adjacent the leading edge **46**. A plurality of mechanical fasteners **56**, shown as two rows of six fasteners, are used to secure the deflector skin **42** and washer bars **54** to the cylinder. The fasteners may take the form of various known types, including for example and without limitation, various screws, nuts, bolts, and washers. In one preferred embodiment, the distance between the rows of fasteners is about 21 and 11/16 inches, forming an angle of about 104 degrees relative to the axis of the cylinder. One or more washer bars or washers can also be used inside the cylinder to secure the fasteners on the inner surface thereof. It should be understood that in alternative embodiments, the deflector skin **42** can be secured to the cylinder **14** with adhesives, with tabs or other snap-fit devices, with guides shaped to receive the ends thereof, by welding, or by other devices available and known to those of skill in the art. Preferably, openings on one of the leading or trailing edges of the deflector skin, or the mating openings formed in the cylinder, which receive the fasteners, are slotted to allow for tolerance build-ups and ease of assembly.

Preferably, the first deflector skin **42** is secured to a lower portion of the cylinder **14**, with a bottom edge **58** of the skin being positioned adjacent to or slightly above the bottom edge **60** of the cylinder. Preferably, the deflector skin **42** covers only a discrete portion of the outer circumferential surface, and preferably at least a portion of the outer surface that is exposed to a lateral impact. In this way, the deflector skin **42** preferably does not extend around the entire periphery of the cylinder, such that the cylinder assembly can be made lighter and at lower costs. In one preferred embodiment, the first deflector skin **42** extends around the circumferential surface of the cylinder and forms an angle A1 between the leading and trailing edges **46, 48** relative to the center of the arc of the

deflector skin or the axis **16** of the cylinder, which centers are preferably substantially coaxial. The angle A1 is preferable greater than about 60°, more preferably greater than about 90° and even more preferably greater than about 100°, although angles less than 60° would of course also work. In one alternative embodiment, the deflector skin can be secured around the entire circumference of the cylinder.

It should be understood that the terms "mounted," "secured," "attached," and variations thereof, mean that one member is connected to another member, whether directly or by way of another member, and regardless of whether other members may be interposed between the members being so mounted, secured or attached. Thus, for example, a first member directly attached to a second member is also attached to a third member by way of the second member being attached to the third member.

Referring again to FIGS. 5-8, a second deflector skin **44** has an inner surface **62** mounted to the outer surface **52** of the first deflector skin **42** and to the cylinder **14**. Preferably, the second deflector skin **44** is substantially flat and has a leading edge **64** and a trailing edge **66**. In other embodiments, the second deflector skin **44** can be provided with a curvature, preferably having an outer convex curved surface. Preferably, the leading edge **64** is secured to the outer surface **52** of the first deflector skin **42** with one row of the fasteners **56** and one washer bar **54** positioned on the outer surface of the second deflector skin **44** and located adjacent the leading edge **46** of the first deflector skin **42**. It should be understood that the second deflector skin **44** can be used independently without the first deflector skin, for example and without limitation by mounting it directly to the cylinder. Conversely, the first deflector skin **42** can be used independently by itself, without the second deflector skin. Preferably, the trailing edge **66** of the second deflector skin **44** is not secured to either the first deflector skin **42** or the cylinder **14**, and remains as a free edge that can flex in response to the impact of a vehicle. In one preferred embodiment, the trailing free edge **66** does not extend rearwardly beyond the tangent **38** of the corresponding cylinder to which it is attached, or substantially outboard of or beyond the vertical plane **40** defined by

the tangents **38**. Preferably, the second deflector skin **44** is non-parallel to and forms an angle A2 with the vertical plane **40**, preferably with its outer surface **68** angled so as to redirect the impacting vehicle back into traffic. Preferably, the angle A2 is greater than 0°, and more preferably between about 5° and 75°, and even more preferably between about 30° and 60°, and most preferably about 52°.

Preferably, the second deflector skin **44** is relatively stiff and resilient and is capable of aiding in the redirection of an errant vehicle back on to the roadway. Preferably, the second deflector skin **44** is stiffer than the first deflector skin **42**, and has a greater thickness than the first deflector skin **42**, although it should be understood that the converse would also work, or alternatively that the deflector skins can be made of the same materials and have the same thicknesses. For example, in one preferred embodiment, the second deflector skin is made of 14 gauge HR (hot rolled) sheet. Of course, other materials, including other steels, and constructions such as a laminate, would also work as explained above with respect to the first deflector skin. Preferably, the material of the second deflector skin has a lower coefficient of friction relative to the vehicle or wheel than does the cylinder. In addition, the material of the first and second deflector skins preferably has a tensile yield strength of greater than about 4 ksi, more preferably greater than about 5 ksi, and even more preferably greater than about 20 ksi. In one preferred embodiment, the second deflector skin has a width of about 8 inches and a length of about 24 inches. Preferably, the second deflector skin **44** is vertically aligned with respect to the first deflector skin **42** in an overlapping relationship therewith, and with the leading edges thereof being preferably substantially flush. The dimensions and materials of the cylinder and deflector skins are meant to be exemplary rather than limiting, and larger and smaller cylinders and skins made out of a variety of materials would also work.

In one preferred embodiment, the trailing free edge **66** of the second deflector skin **44** does not extend rearwardly beyond the tangent **38** of the corresponding cylinder **14** to which the deflector skin **44** is attached, but does extend up to or outwardly from the vertical plane **40** defined by the tangents. In

other preferred embodiments, the free edge **66** terminates inwardly of the vertical plane **40**.

In one alternative preferred embodiment, shown in FIG. 10, the trailing free edge **66** of the second defector skin **44** extends rearwardly beyond a plane **70** formed tangentially to the cylinder **14** and oriented substantially perpendicular to the plane **40** formed by the tangents **38**. Preferably, the trailing free edge **66** extends rearwardly of the leading edge **64** of the second deflector skin **44** secured to the next adjacent cylinder **14** positioned rearwardly thereof.

It should be understood that other deflector skins could be mounted on top of or between the aforedescribed first and second deflector skins without departing from the scope of the invention. Likewise, other components, surface treatments and the like can be applied to or mounted on the deflector skins.

In operation, the crash cushion **2** is designed to absorb the energy of a vehicle axially impacting a front **4** of the crash cushion and redirecting the vehicle back onto the roadway when impacting a side **8** of the cushion or array. For example, when a vehicle impacts the front **4** of the array, the cylinders **14** are flattened along the longitudinal direction **20**. Depending on the configuration of the system, the cylinders may be guided by a rail, as explained above, or may be tethered or secured together by other fasteners and devices. Moreover, one or more compression elements can be designed to absorb the energy of the vehicle, if desired.

During this sequence, as shown in FIG. 9, the first deflector skins **42,** which preferably extend along only a portion of the sides of the outermost surface of the cylinders **14** defining the impact side of the array or cushion, also bend or deform with the cylinders **14** in the longitudinal direction. Preferably, the first deflector skins **42,** which are relatively thin and resilient, are capable of being restored to substantially their original shape, whether by way of self-restoration or with the aid of the self-restoring cylinders to which they are attached. During the front, axial impact, the second deflector skin **44,** which is preferably secured along only the leading edge **64,** is not bent or otherwise deformed, but rather simply moves with the cylinder **14** and rotates as the cylinder is compressed as shown in

FIG. 9. After the incident, the cylinders, including those with and without deflector skins, can be restored to substantially their original shape. Those cylinders that are not restorable can be replaced. Likewise, deflector skins that cannot be restored, or are otherwise damaged beyond use, can be easily replaced on the corresponding cylinder.

When a vehicle impacts the side **8** of the array, the deflector skins **42**, **44** redirect the vehicle smoothly back onto the roadway. For example, when the angle of impact is relatively large relative to the vertical plane **40**, the second deflector skin **44** redirects the wheel or other portion of the vehicle towards the rear **6** so as to avoid pocketing in the array of cylinders. When the angle is more shallow, the vehicle will glance off one or both of the first and second deflector skins **42, 44**. The deflector skins **42, 44**, with their relatively low coefficients of friction, allow the vehicle to slide along the deflector skins **42, 44** and also prevent the vehicle from gouging the cylinder **14** or otherwise becoming snagged thereon. Moreover, the deflector skins **42, 44** increase the stiffness of the cylinders in the lateral direction and thereby help prevent the vehicle from pocketing in the cylinders.

When a vehicle impacts the side of the crash cushion shown in FIG. 10, the free edge **66** of the impacted second deflector skin **44** flexes or bends inwardly towards the second deflector skin **44** on a next adjacent cylinder. Since the free edge **66** extends rearwardly of the leading edge **64** of the next adjacent deflector skin, the deflector skins in combination act as overlapping members to prevent the vehicle from pocketing in the gaps **70** formed between the cylinders.

By securing individual deflector skins **42, 44** to corresponding individual cylinders **14**, various configurations of crash cushions can be configured and deployed easily and inexpensively due to the diminished amount of customization of the various components. In essence, the system is modular, permitting like components to be configured and reconfigured as needed.

Although the present invention has been described with reference to preferred embodiments, those skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the

invention. As such, it is intended that the foregoing detailed description be regarded as illustrative rather than limiting and that it is the appended claims, including all equivalents thereof, which are intended to define the scope of the invention.